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06 Chemical Coordination and Integration

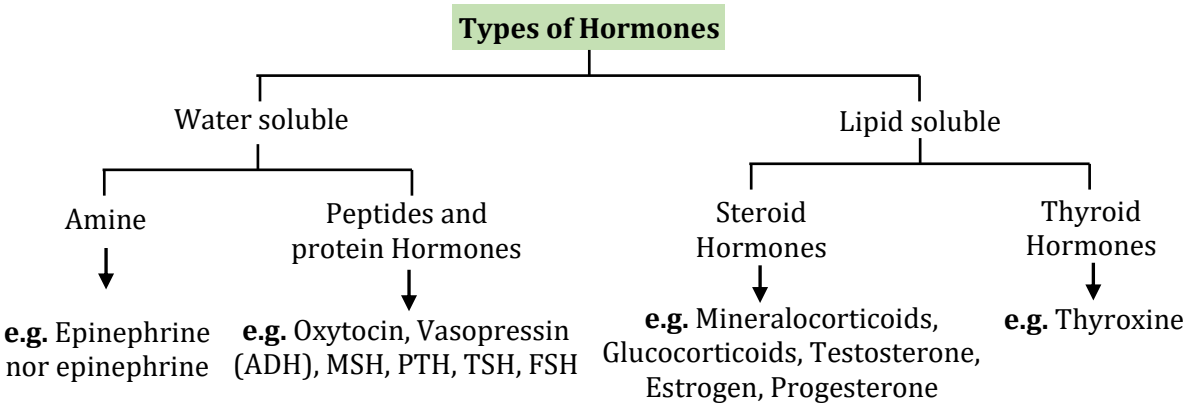
1. Introduction :

- The neural system and the endocrine system jointly co-ordinate and regulate the physiological functions in the body.
- The neural co-ordination is fast very exact and short lived, whereas chemical co-ordination is usually slow, widespread and long lasting.
- All cells of our body are not innervated by nerve fibres but the cellular function need to be continuously regulated so a special kind of coordination and integration has to be provided. This function is carried out by hormones.

2. Endocrine Glands and Hormones :

- Endocrine glands lack ducts and are hence, called **ductless glands**. Their secretions are called **hormones**.
- **Classical definition of hormone –** A chemical produced by endocrine glands and released into the blood and transported to a distantly located **target organ**.
- **Current scientific definition of hormones – Non-nutrient chemicals** which act as **intercellular messengers** and are produced in trace amounts.
- The new definition covers a number of new molecules in addition to the hormones secreted by the organised endocrine glands.
- **Invertebrates** possess very simple endocrine systems with few hormones whereas a large number of chemicals act as hormones and provide coordination in the **vertebrates**.

CHEMICAL NATURE OF HORMONES TABLE



Human Endocrine System :

- The endocrine glands and hormone producing diffused tissues/cells located in different parts of our body constitute the endocrine system. Pituitary, pineal, thyroid, adrenal, pancreas, parathyroid, thymus and gonads (testis in males and ovary in females) are the organised endocrine bodies in our body.

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- In addition to these, some other organs, e.g., gastrointestinal tract, liver, kidney, heart also produce hormones. A brief account of the structure and functions of all major endocrine glands and hypothalamus of the human body is given in the following sections.

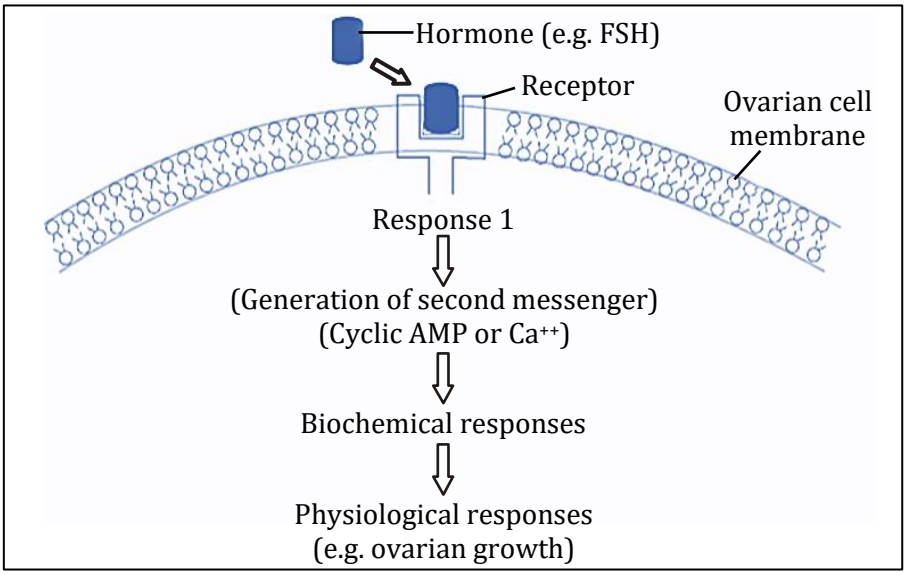
Organised endocrine gland : Where hormone producing cells are present in cluster/tissue form called organised endocrine gland.
Examples : Pituitary, Pancreas, Parathyroid, Pineal, Thyroid, Thymus, Adrenal and Gonads (Testis in males and Ovary in females.
Non-organised endocrine gland : Where hormone producing cells are present in scattered form called non-organised or diffused endocrine tissue.
Example : Heart, Liver, Kidney, Gastrointestinal tract

3. Mechanism of Hormone Action :

- Hormones are two types :
  (i) Water soluble hormones
  (ii) Lipid soluble hormones
- Hormones produce their effects on target tissues by binding to specific proteins called **hormone receptors** located in the target tissues only.
- Hormone receptors present **on the cell membrane** of the target cells are called **membrane-bound receptors** and the receptors present **inside the target cell** are called **intracellular receptors**. Mostly nuclear receptors (present in the nucleus). Binding of a hormone to its receptor leads to the formation of a **hormone-receptor complex.**
- Each receptor is specific to one hormone only and hence **receptors are specific**.
- Hormone-Receptor complex formation leads to certain biochemical changes in the target tissue. Target tissue metabolism and hence physiological function are regulated by hormone

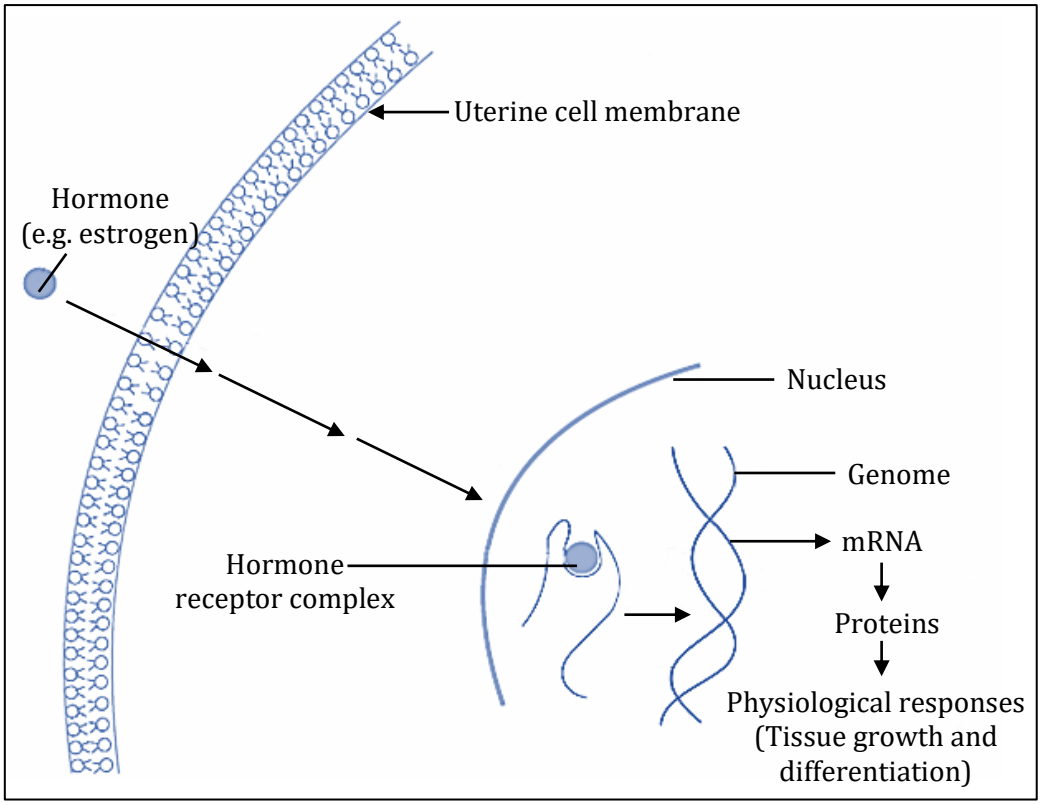
(A) Water Soluble Hormones :

Hormone which interact with membrane bound receptor normally do not enter the target cell, but generate secondary messenger (**e.g.** cyclic GMP / cyclic AMP, IP_3, Ca^{++} etc.) which in turn regulate cellular metabolism.



(B) Lipid Soluble Hormone :

Hormone which interact with intracellular receptor (Steroid, iodothyronine) mostly regulate gene expression or chromosome function by the interaction of hormone receptor complex with the genome. **Cumulative biochemical action results in physiological and developmental effects**.



On the basis of their chemical nature, hormones can be divided into groups :

(i) **Peptide, polypeptide, protein hormones** (**e.g.,** insulin, glucagon, pituitary hormones, hypothalamic hormones, etc.)

(ii) **Steroids** (**e.g**., cortisol, testosterone, estradiol and progesterone)

(iii) **Iodothyronines** (thyroid hormones)

(iv) **Amino-acid derivatives** (**e.g**., epinephrine).

BEGINNER'S BOX-1 — MECHANISM OF HORMONE ACTION

1. Following are the example of organised gland except

(1) Pituitary (2) Pineal (3) Thyroid (4) Kidney

2. Which of the following characteristics is not mentioned in current scientific definition of hormone?

(1) Non-antigenic substance (2) Non-nutrient chemical

(3) Act as intercellular messenger (4) Produced in trace amount

3. A hormone which binds with membrane bounded receptor except one :

(1) Insulin (2) Thyrocalcitonin

(3) Oxytocin (4) Progesterone

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4. Which of the following hormone not binds with cytoplasmic or nuclear receptor?
(1) Cortisol (2) Aldosterone (3) Insulin (4) Oestrogen

5. Body co-ordination is exhibited by-
(1) Blood vascular system (2) Nervous system
(3) Endocrine system (4) Nervous and endocrine system

6. Hormones may be-
(1) Amino acid derivatives (2) Peptides
(3) Steroids (4) All of the above

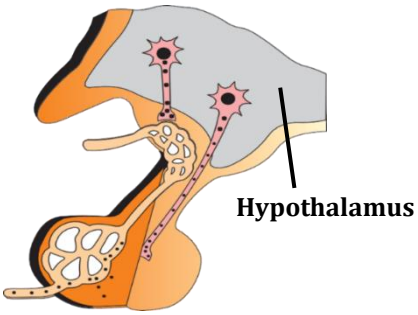
7. Endocrine glands produce or Action of endocrine glands is mediated through-
(1) Hormones (2) Enzymes (3) Minerals (4) Vitamins

4. Hypothalamus :

- The hypothalamus is the basal part of diencephalon (forebrain) and it regulates a wide spectrum of body functions.
- It contains several groups of **neurosecretory cells** called **nuclei** which produce hormones. These hormones regulate the synthesis and secretion of pituitary hormones.
- However, the hormones produced by hypothalamus are of two types, the **releasing hormones** (which stimulate secretion of pituitary hormones) and the **inhibiting hormones** (which inhibit secretions of pituitary hormones).

For example :

- A hypothalamic hormone called **Gonadotrophin releasing hormone (GnRH)** stimulates the pituitary synthesis and release of gonadotrophins.
- On the other hand, **somatostatin** from the hypothalamus, inhibits the release of growth hormone from the pituitary.
- These hormones originating in the hypothalamic neurons, pass through axons and are released from their nerve endings.



- These hormones reach the pituitary gland through a portal circulatory system and regulate the functions of the anterior pituitary.
- The posterior pituitary is under the direct neural regulation of the hypothalamus.

5. Pituitary Gland :

- On the basis of development pituitary gland is completely ectodermal.
- It is located in the *sella.tursica* (bony cavity) of sphenoid bone.
- This gland is **attached to the hypothalamus** through a stalk which is called as **infundibulum**.
- It is **divided anatomically** into an adenohypophysis (anterior pituitary) and a neurohypophysis (posterior pituitary).
- **Adenohypophysis** consists of two portions, pars distalis and pars intermedia.

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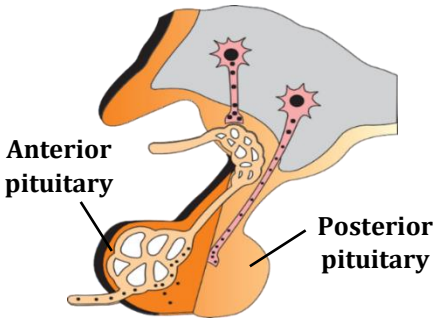
- The **pars distalis** region of pituitary, commonly called anterior pituitary, produces growth hormone (GH), prolactin (PRL), thyroid stimulating hormone (TSH), adrenocorticotrophic hormone (ACTH), luteinizing hormone (LH) and follicle stimulating hormone (FSH).
- **Pars intermedia** secretes only one hormone called melanocyte stimulating hormone (MSH). However, in humans, the pars intermedia is almost merged with pars distalis.
- **Neurohypophysis** (pars nervosa) also known as posterior pituitary, stores and releases two hormones called oxytocin and vasopressin, which are actually synthesised by the hypothalamus and are transported axonally to neurohypophysis.



Posterior Lobe or Neurohypophysis :

- Posterior lobe of pituitary gland is 1/4th part of total gland. It is just like nervous tissue, because in it, the terminal ends of the axons of neurosecretory cells of hypothalamus are swollen.

(A) Hormones Secreted by Neurohypophysis :

(i) Oxytocin or Pitocin or Birth Hormone :

- Oxytocin acts on the **smooth muscles** (non-striated) of our body and stimulates their contraction.
- In females, it stimulates a **vigorous contraction of uterus** at the time of child birth, and **milk ejection** from the mammary gland.
- It is the main **parturition hormone**. It stimulates the fast/ rapid contractions and expansions of non- striated muscles of the uterine wall at the last moment of gestation period (pregnancy). Due to this uterine contractions, **labour pains** start just before child birth.
- This hormone is secreted by pituitary glands of mother at the time of parturition.
- Oxytocin hormone contracts the myoepithelial cells present at all the sides of alveoli of mammary glands. Thus, it helps in milk ejection so it is also called **milk let down hormone**.
- In female, this hormone related with emotion. Even thought, cry or sound of baby can bring about release of this hormone in lactating mother.

(ii) ADH or Vasopressin or Pitressin :

- It acts mainly at the kidney and stimulates reabsorption of water and electrolytes by the distal convoluted tubules (in DCT and collecting duct of nephrons) and thereby reduces loss of H_2O through urine **(Diuresis)**, Hence, it is also called as **"Anti-diuretic hormone (ADH)"**
- Hyposecretion of ADH causes **"Diabetes insipidus"** (taste less urine or water drinker's disease), which is characterised by polyuria, diluted urine, dehydration, excessive thirst (polydipsia) low BP (hypotension) etc.
- Intake of coffee, tea and excess alcohol etc. decreases the secretion of ADH.

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(B) Hormones Secreted by Adenohypophysis :

(i) Growth Hormone or Somatotropic Hormone [G.H. or S.T.H] :

Effect on growth–

(i) Promotes elongation of bones

(ii) GH promotes mitosis & increases number of cells in many visceral organs e.g. liver

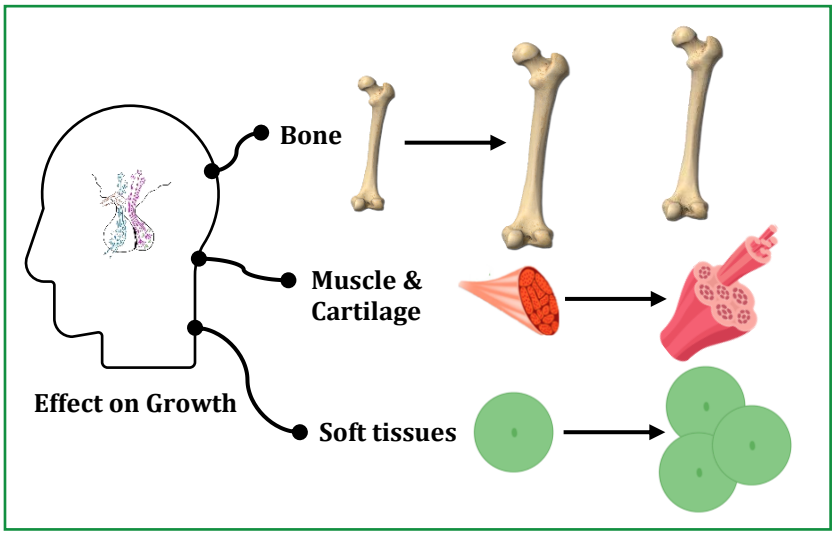
(iii) GH stimulates growth of muscle and cartilage

Effect on metabolism

Fat : Increases lipolysis. Under the influence of growth hormone fat is used for energy in preference to carbohydrate and protein.

Carbohydrate : GH decreases uptake of glucose in the cells, so it is also called **diabetogenic hormone**.

Protein : GH increases amino acid uptake by the cells of the liver & muscles & helps in protein synthesis.



Diseases due to hyposecretion or hypersecretion of somatotropin hormone :.

(a) Hyposecretion of STH : Due to deficiency of STH in **childhood** or **adolescence**, **pituitary dwarfism** is observed.

- Dwarfism due to the defect of pituitary is called **Ateliosis**.
- Clowns of circus are such dwarfs, they are called ***midgets***.
- Intelligence and alertness is normal but sexual maturation is delayed.

(b) Hypersecretion of STH :

(i) Due to hypersecretion of GH in **childhood**, the bones of legs & hands become very long and height of that person increases very much. Body becomes imbalanced. This disease is called **Gigantism**.

(ii) Excess secretion of growth hormone in **adults** specially in middle age can result in severe disfigurement like excess enlargement of bones of face, vertebral column and fore limbs, called **Acromegaly**, which may lead to serious complications, and premature death if unchecked.

The disease is hard to diagnose in the early stages and often goes undetected for many years, until changes in external features become noticeable.

Over secretion of GH = Gigantism = Abnormal growth of body

Low secretion of GH = Pituitary dwarfism = Stunted growth of body

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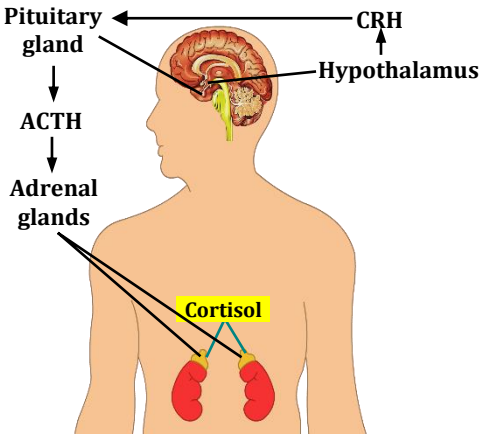
(ii) Prolactin / Lactotrophic Hormone (PRL/LTH) :

- Regulates the **growth of mammary glands** and **formation of milk**.
- Responsible for lactation after delivery.
- **Hormone of maternity**.



(iii) Adrenocorticotrophic Hormone (ACTH) :

- Stimulates the synthesis and secretion of steroid hormones from adrenal cortex. (Mainly Glucocorticoids)

(iv) Thyrotrophic [T.T.H OR T.S.H.] or Thyroid Stimulating Hormone :

- T.S.H. stimulates thyroid gland to secrete thyroxine. TSH helps in almost all steps of the thyroid hormone synthesis & it causes growth of thyroid gland.
- Secretion of **TSH** is stimulated by Thyrotrophin releasing factor of hypothalamus.

(v) Follicle Stimulating Hormone [FSH] :

- It is secreted in male and female both.
- In males, it stimulates **spermatogenesis** and normal functioning of seminiferous tubules.
- In females, it stimulates **oogenesis** and development of Graafian follicles in ovary.
- Estrogen hormone that is secreted by Graafian follicles is also affected by FSH.

(vi) Luteinizing Hormone [LH Or ICSH] or Interstitial Cell Stimulating Hormone :

- It stimulates **ovulation** in female. As a result of this corpus luteum is formed.
- Hormone **progesterone** which is secreted by corpus luteum is also stimulated by L.H.
- In men **LH** is called **ICSH**. It affects the Leydig's cells or Interstitial cells of testes and stimulates the secretion of male hormone **"Testosterone"**.
- **FSH** and **LH** both are called **gonadotrophic hormone GTH**.
- FSH and LH act in combined form so these are called **synergesic** hormone.
- Gonadotrophic hormones (FSH & LH) secretion starts during puberty. Their secretion is regulated by hypothalamus.

Melenocyte Stimulating Hormone (Msh) / Intermedin

HORMONE	TARGET ORGAN	FUNCTIONS
Melanocyte Stimulating hormone (MSH) or (Intermedin)	SKIN (In man MSH is Secreted by anterior Lobe because middle Lobe is ill developed)	Regulate pigmentation of skin (**Darkening**). It is responsible for colour change in Amphibian and Reptiles (Metachrosis). MSH is functional in Poikilothermals. Function in humans is still unknown.

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BEGINNER'S BOX-2 PITUITARY & HYPOTHALAMUS

1. Which of the following adenohypophysis hormone have diabetogenic effect ?
(1) PRL (2) TSH (3) LH (4) GH

2. Abnormal growth of bones due to hypersecretion of growth hormone in adult is known as:
(1) Acromegaly (2) Dwarfism (3) Gigantism (4) Both (1) and (2)

3. Which of the following hormone induces ovulation ?
(1) FSH (2) LH (3) Vasopressin (4) Oxytocin

4. Hypophysial hormone that stimulates reabsorption of water and electrolyte by the distal tubules of kidneys is:
(1) Oxytocin (2) Aldosterone (3) Cortisol (4) Vasopressin

5. The hyposecretion of posterior pituitary hormone cause :-
(1) Cretinism (2) Diabetes insipidus
(3) Goitre (4) Diabetes mellites

6. Neurohypophysis releases :-
(1) Vasopressin (2) Oxytocin
(3) Oxytocin & prolactin (4) Vasopressin & oxytocin

7. "Sella turcica" is a :-
(1) Depression in skull enclosing pituitary (2) Cavity of skull enclosing ears
(3) Covering of testis (4) Kind of endocrine gland

8. Growth hormone is produced in :-
(1) Adrenals (2) Thyroid (3) Pituitary (4) Thymus

9. MSH Produced by the pars intermedia of pituitary causes in lower vertebrates: -
(1) Darkening of skin (2) Light coloration of skin
(3) Both (4) None of these

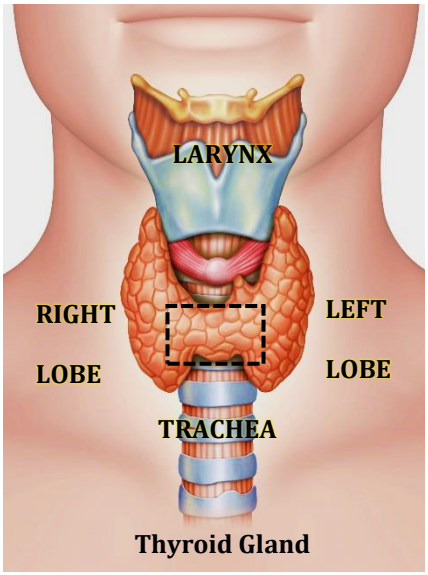
6. Thyroid Gland :

- The thyroid gland is composed of two lobes which are located on either side of the trachea.
- Both the lobes are interconnected with a thin flap of connective tissue called isthmus (non-glandular part).

  Origin : Endodermal

  Position : Located in the neck between the trachea and larynx.

  Structure : 'H' shape, Largest Endocrine gland.
- The thyroid gland is composed of **follicles** and **stromal tissues**.
- Each thyroid follicle is composed of follicular cells, enclosing a cavity. These follicular cells synthesise two hormones, **tetraiodothyronine** or **thyroxine** (T_4) and **triiodothyronine** (T_3).



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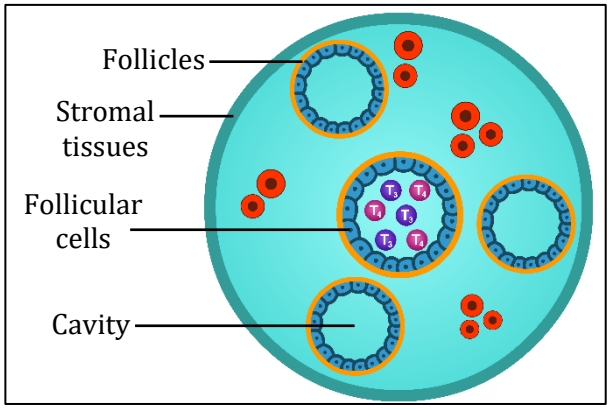
- Thyroid is the **only endocrine gland** in the body which stores its hormone (for 2-3 months) in its inactive state. Synthesis of Thyroxine is stimulated by TSH.
- Thyroglobulin is the stored form of Thyroid hormones in the follicles of thyroid gland sufficient for body supply of thyroxine for the next 3 months.
- Iodine is essential for the normal rate of hormone synthesis in the thyroid.



- Thyroid gland requires approximately **"120 µg" Iodine per day** for the production of thyroxine.
- **Minimum intake** of iodine is **200 µg/day**.
- If iodine intake is **< 50 µg/day**, then **thyroid disorders** may develop.

(A) Function of Thyroid Hormone :

- Regulates basal metabolic rate **(BMR)** of the body. **(Calorigenic Hormone)**
- Supports the process of **red blood cell formation**.
- Thyroid hormones control the metabolism of carbohydrates, proteins and fats.
- Maintenance of **water and electrolyte balance** is also influenced by thyroid hormones.
- It is responsible for physical, mental and sexual growth.
- Required for the development of the nerve fibres and their myelination.
- It stimulates the **metamorphosis of tadpole larva** in amphibians. Due to its deficiency, larva does not metamorphose into adult.

(B) Thyroid Disorders :

Hyposecretion of Thyroid or Hypothyroidism :

- **Goitre –** Deficiency of iodine in our diet results in hypothyroidism and **enlargement of the thyroid gland.**

- **CRETINISM –** Hypothyroidism **during pregnancy** causes defective development and maturation of the growing baby leading to **stunted growth (cretinism), mental retardation, low intelligence quotient, abnormal skin, deaf-mutism**, etc.

- **MYXOEDEMA –** **In adult women**, hypothyroidism may cause **menstrual cycle to become irregular.** Falling of hair, loose and swollen skin, deposition of adipose fat are other symptoms related to it.

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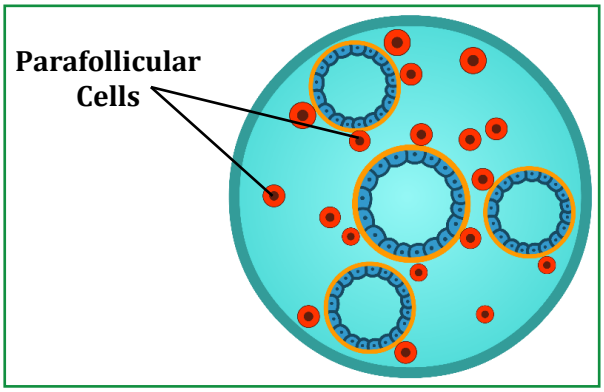
Hypersecretion of Thyroid or Hyperthyroidism :

- Due to cancer of the thyroid glands or due to development of nodules the rate of synthesis and secretion of thyroid hormones is increased to abnormal high levels leading to a condition called **hyperthyroidism**.
- **GRAVE'S DISEASE or EXOPHTHALMIC GOITER or Basedow disease** enlargement of thyroid gland, protrusion of eye balls, increased BMR and weight loss is seen.

Enlarged Gland

(C) Parafollicular Cells :

- These cells are found in the **stroma of thyroid** gland & basal part of follicles. These cells are of **endocrine nature**.
- These cells secrete **thyrocalcitonin (Calcitonin) hormone** which lacks iodine. It enhances the deposition of Ca^{++} in bones, thus **making bones solid and strong.** This hormone is **antagonistic to Collip's hormone or PTH.**
- Thus thyrocalcitonin (TCT) regulates the blood calcium level.

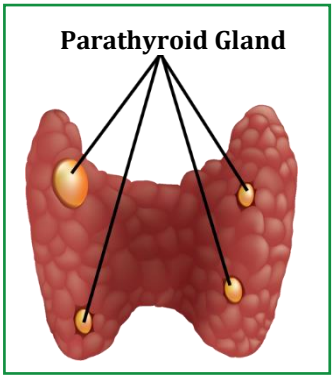


7. Parathyroid Gland :

Origin : Endodermal

Position : Present on the backside of thyroid gland.

Four in number (One pair each in the two lobes of the thyroid gland).



- Parathyroid hormone **(PTH)** or Collip's hormone or **parathormone** is secreted by parathyroid gland.
- It is **polypeptide in nature**.
- The secretion of PTH is regulated by the circulating levels of calcium ions.
  - (i) Increases activity of osteoclast cells and stimulates the process of bone resorption (bone demineralisation/ dissolution) of bones.
  - (ii) Also stimulates reabsorption of Ca^{++} by renal tubules.
  - (iii) Increases Ca^{++} absorption from the digested food.
  - (iv) Increases urinary excretion of PO_4^{3-}.

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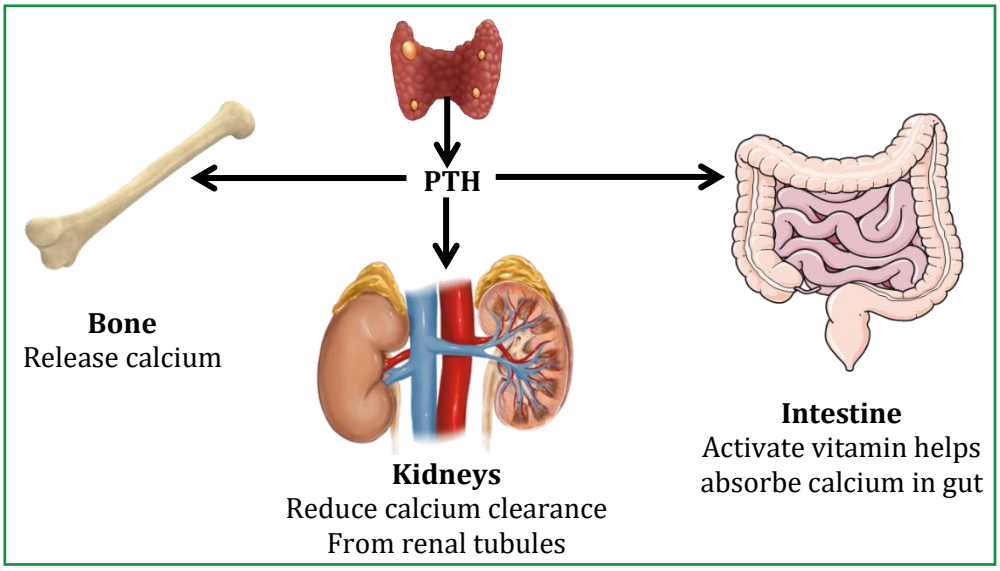
(A) Functions of Parathyroid Gland :



- Increase in blood calcium level causes Hypercalcemia
- Decrease in blood phosphate level causes Hypophosphatemia
- Parathyroid hormone (PTH) increases the Ca^{2+} levels in the blood.
- **Parathormone** is **essential for survival** because it significantly contributes to "homeostasis" by **regulating the amount of calcium and phosphate ions in the ECF.**
- Calcium is key element in many physiological functions like proper permeability of cell membranes, muscular activities, nerve impulse conduction, heart-beat, blood coagulation, bone formation, fertilization of ova, etc.

(B) Irregularities of Parathyroid Gland :

(i) Hypoparathyroidism

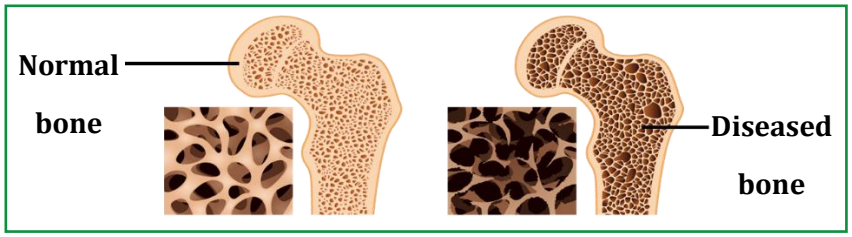
Tetany (Hypocalcaemia)

- Amount of Ca^{2+} in ECF decreases.
- Muscles and nerves get unnecessarily irritated and start convulsion and cramping.

(ii) Hyperparathyroidism

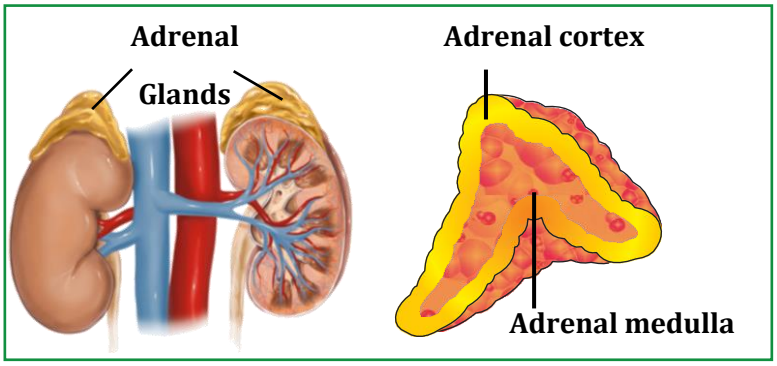
Osteoporosis

- Due to hypersecretion of PTH, osteoclast cells feed excess amount of bone unnecessarily.
- As a result of this, bones become brittle and weak. This condition is called as Osteoporosis.



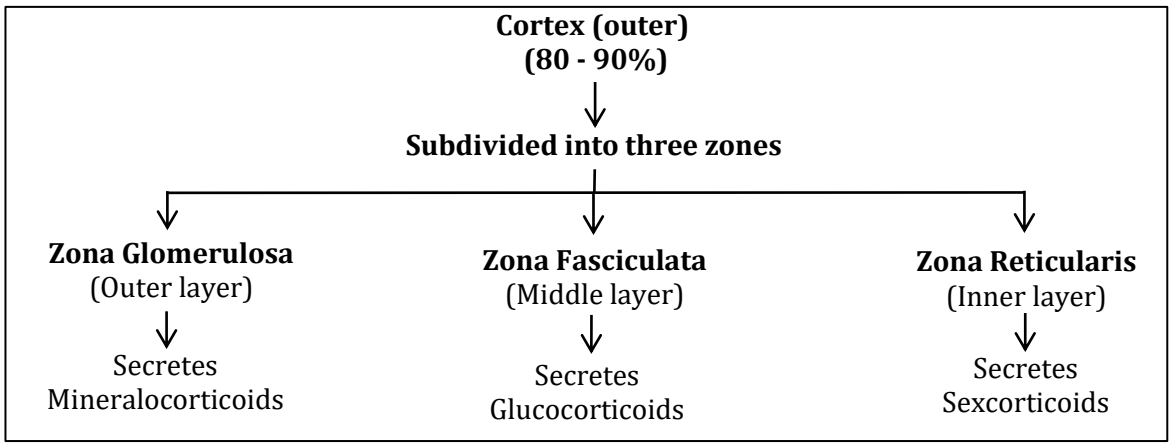
8. Adrenal Gland :

- Our body has one pair of adrenal glands, one at the anterior part of each kidney.
- The gland is composed of two types of tissues –
  (i) The centrally located tissue is called the **adrenal medulla**
  (ii) Outside this lies the **adrenal cortex**



- Adrenal Gland divided in to 2 parts
  (i) Outer cortex (80 - 90%) – Mesodermal in origin
  (ii) Inner Medulla (10 - 20%) – Ectodermal in origin

(A) Adrenal Cortex :



- The adrenal cortex secretes many hormones, commonly called as corticoids.

Zona Glomerulosa (Mineralocorticoids) :

- Corticoids, which **regulate the balance of water** and **electrolytes** in our body are called mineralocorticoids. **Aldosterone is the main mineralocorticoid in our body.**
- Aldosterone acts mainly at the renal tubules and stimulates the reabsorption of Na^+ and water and excretion of K^+ and phosphate ions. Thus, aldosterone helps in the –
  (i) Maintenance of electrolytes
  (ii) Maintenance of body fluid volume
  (iii) Maintenance of osmotic pressure
  (iv) Maintenance of blood pressure.
- Aldosterone hormone is also known as salt retaining hormone. It increases sodium concentration in ECF.

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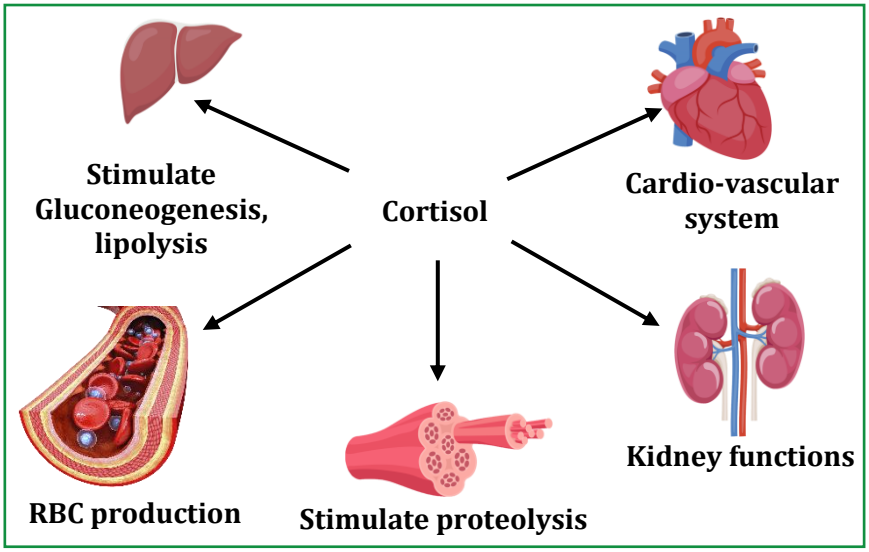
Zona Fasciculata (Glucocorticoids) :

- Hormone – Glucocoricoids / Cortisol / Hydrocorticosterone / diabetogenic hormone / **"Life - saving hormone"**
- The corticoids, which are involved in **carbohydrate metabolism** are called **glucocorticoids**. In our body, **cortisol** is the main glucocorticoid.
- Glucocorticoids stimulate gluconeogenesis, lipolysis and proteolysis; and inhibit cellular uptake and utilisation of amino acids.
- Cortisol is also involved in maintaining the cardio-vascular system as well as the kidney functions.
- Glucocorticoids, particularly cortisol, produces anti-inflammatory reactions and suppresses the immune response (Now a days, Cortisol is used in transplantation of organs).
- Cortisol stimulates the RBC production.

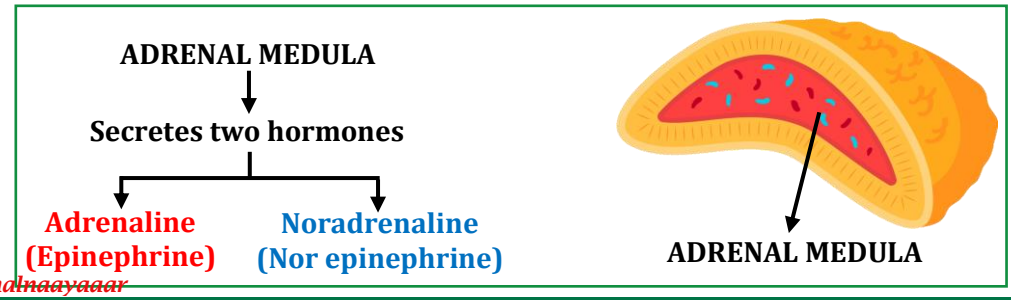


Zona Reticularis (Sex Corticoids) (Sex Hormones) (Gonadocorticoids) :

- **Androgens** in males and **estrogens** in females.
- Small amounts of **androgenic steroids** are also secreted by the adrenal cortex which play a role in the growth of axial hair, pubic hair and facial hair during puberty.
- Both hormones are secreted in both male and female, but hormones secreted by gonads inactivate opposite hormones secreted by Adrenal gland.

(B) Adrenal Medulla :

- Adrenaline & nor-adrenaline are commonly called as Catechalomines.
- These are rapidly secreted in response to stress of any kind and during emergency situations so, called emergency hormones or hormones of flight and fight.



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Functions of Catecholamines :

- It **increases alertness** and **pupilary dilation**. It also constricts the **errector pilli muscle** of hair, due to this hair are raised **(PILOERECTION)** and **increases sweating** by stimulating sweat glands.
- **Increases the heartbeat**, the **strength of heart contraction** and thus circulation of blood becomes faster.
- The hormone stimulates the trachea and bronchi muscles to relax, as a result of it, **rate of respiration** is **increased**. So, adrenaline hormone is used to cure **asthma**.
- The hormone enhances the flow of blood by vasodilation of blood vessels of brain, heart, liver and skeletal muscles.
- It constricts the blood vessels of skin (Vasoconstriction).
- Adrenal gland is also known as ***4 - S gland***

4–S
- S – Sugar metabolism
- S – Salt retaining actions
- S – Sex hormones
- S – Stress reactions

ADRENAL GLAND = "TRIPLE-F – GLAND"

F = FEAR
F = FLIGHT
F = FIGHT

- It also stimulates the **breakdown of glycogen** resulting in an **increased concentration of glucose in blood**.
- In addition, it also stimulates the breakdown of lipids and proteins.
- The hormone stimulates contraction in spleen, as a result of it, spleen pours its stored blood into blood stream.
- It checks the secretion of saliva and reduces the peristaltic movements in alimentary canal.
- Due to the effect of this hormone, clotting period of blood is reduced.

Control of Adrenal Secretion :

- ACTH of anterior pituitary controls the secretion of adrenal cortex (mainly glucocorticoids).
- Secretion of mineralocorticoids is controlled by Renin (Kidney).
- Adrenal medullary hormones are controlled by nervous system.

Disorder related to Adrenal Gland (cortex) (HYPOSECRETION) :

Addison's Disease (Symptoms)

(i) Stress and fatigue
(ii) Hyperpigmentation/bronzing of skin
(iii) Acute weakness
(iv) Hypoglycaemia

Disorder related to Adrenal Gland (cortex) (HYPERSECRETION) :

- Over secretion of Cortisol leads to the excess break down of body fat (lipolysis).
- This fat is deposited in unusual body areas like face and upper abdominal region which is characterised by - moon face, fish mouth, buffalo hump (Cushing's Syndrome).

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BEGINNER'S BOX-3 THYROID, PARATHYROID AND ADRENAL GLAND

1. Non iodinised hormone secreted by thyroid gland is :
(1) T_3 (2) T_4 (3) Calcitonin (4) Oxytocin

2. Largest endocrine gland is:-
(1) Adrenal gland (2) Thyroid gland (3) Thymus (4) Kidney

3. The basal metabolic rate (BMR) in body cells is regulated by: -
(1) Parathyroid (2) Thyroid (3) Pituitary (4) Thymus

4. Hypothyroidism in adults causes: -
(1) Addison's disease (2) Myxoedema (3) Sterility (4) Cretinism

5. Which gland stores hormone in intercellular space before its secretion into blood?
(1) Pancreas (2) Thyroid (3) Testis (4) Ovary

6. The secretion of PTH in man is regulated by :
(1) Circulating level of sodium.
(2) Circulating level of potassium.
(3) Circulating level of calcium.
(4) Circulating level of magnesium.

7. Removal of Parathyroid in human beings result in :-
(1) Tetany (2) Simmond's disease
(3) Myxoedema (4) Addison's disease

8. Parathormone controls :-
(1) Fatty acid metabolism
(2) Sodium and potassium metabolism
(3) Calcium and phosphate metabolism
(4) Protein metabolism

9. Deficiency of adrenal cortex hormone may cause :
(1) Simmond's disease (2) Acromegaly
(3) Cushing's syndrome (4) Addisson's disease

10. Epinephrine is :-
(1) Secreted from pancreas and decreases heart beat
(2) Secreted from adrenal medulla and increases heart beat
(3) Secreted from adrenal medulla and decreases heart beat
(4) Secreted from pancreas and increases heart beat

11. Hormones produced by adrenal cortex and gonads (sex hormone) are chemically :-
(1) Proteinous (2) Steroids (3) Glycoprotein (4) Phenolic compound

12. The function of norepinephrine is :-
(1) Almost similar to epinephrine (2) Similar to ADH
(3) Opposite to epinephrine (4) Opposite to ADH

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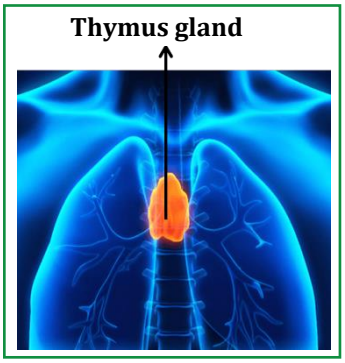
9. Thymus Gland :

Origin :- Endodermal

Position :- The thymus gland is a **lobular structure** (bilobed) located between lungs behind sternum on the ventral side of aorta.

Hormone secrete :- Thymosin

Nature of thymosin :- Proteinaceous.



Function of Thymus Gland :

- The thymus plays a **major role in the development of the immune system.**
- This gland secretes the peptide hormones called **thymosins**.
- Thymosins play a major role in the **differentiation of T-lymphocytes**, which provide **cell-mediated immunity**.
- Thymus provide cell mediated immunity so thymus is also called **"Throne of immunity"** and **"Training school of T- lymphocytes"**.
- In addition, thymosin also **promote production of antibodies** to provide **humoral immunity**.
- Thymus is **degenerated in old individuals** resulting in a decreased production of thymosins. As a result, the immune **responses of old persons become weak.**

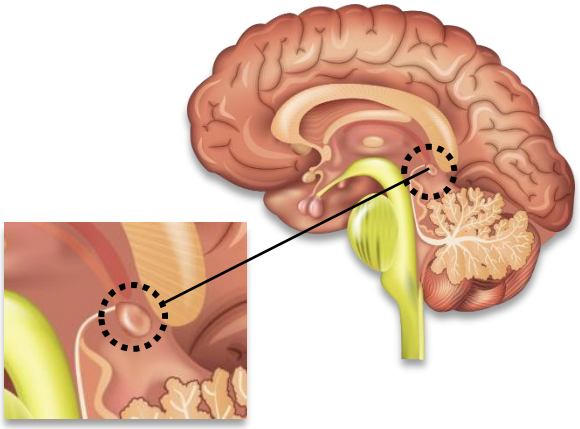
10. Pineal Gland :

Origin :- Ectodermal

Position :- It is located at the dorsal side of forebrain (Dorsal side of Diencephalon). **Also known as Epiphysis cerebri.**

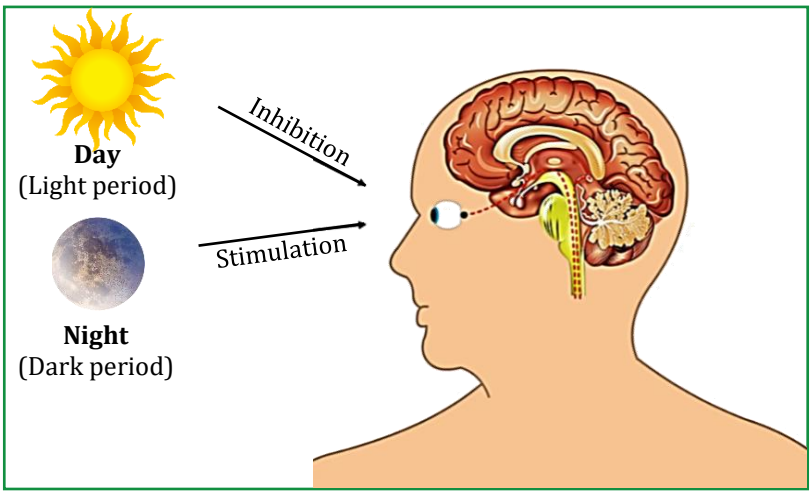
Nature of hormone :- Amino acid derivative

Hormone secreted :- Melatonin



Function of Pineal Gland :

- Melatonin plays a very important role in the **regulation of a 24-hour (diurnal/circadian) rhythm of our body.**
- For example, it **helps in** maintaining the normal rhythms of **sleep-wake cycle, body temperature.**
- Melatonin also **influences metabolism, pigmentation, menstrual cycle** and our **defense capability.**
- It **regulates** our **sexual maturity.**



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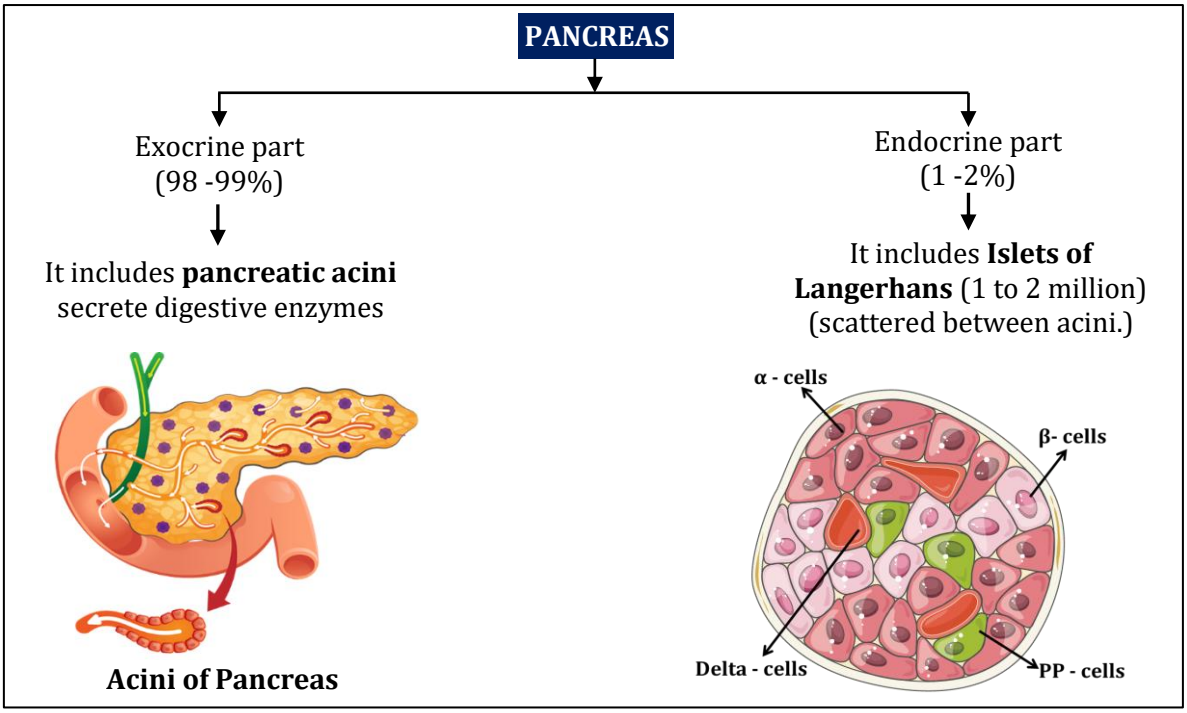
11. Pancreas :

Origin : Endodermal

Position : Elongated organ situated between the limbs of the 'C' shaped duodenum.

Nature : Heterocrine / Mixed / Composite gland / Compound (both exocrine and endocrine).

- The exocrine portion secretes an alkaline pancreatic juice containing enzymes and the endocrine portion secretes hormones, insulin and glucagon.



- The two main types of cells in the Islet of Langerhans are called α-cells and β-cells.

(i) α-cells :

- Secrete **glucagon.**
- It is a **peptide hormone.**
- Plays an important role in **maintaining the normal blood glucose levels.**
- Acts mainly on the **liver cells** (hepatocytes).
- Stimulates **glycogenolysis** resulting in an increased blood sugar (hyperglycemia).
- In addition, this hormone stimulates the process of **gluconeogenesis** which also contributes to **hyperglycemia**.
- Glucagon **reduces the cellular glucose uptake** and utilisation. Thus, glucagon is a **hyperglycemic hormone**.

(ii) β-cells :

- Secrete **insulin.**
- Insulin is a **peptide hormone**, which plays a major role in the **regulation of glucose homeostasis**.
- Insulin acts mainly on **hepatocytes** and **adipocytes** (cells of adipose tissue), and enhances cellular glucose uptake and utilisation. As a result, there is a rapid movement of glucose from blood to hepatocytes and adipocytes resulting in decreased blood glucose levels **(hypoglycemia)**.
- Insulin also stimulates **conversion of glucose to glycogen (glycogenesis)** in the target cells.
- **The glucose homeostasis in blood is thus maintained jointly by the two – insulin and glucagon.**

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Hyposecretion of Insulin :

Diabetes mellitus –

- **Prolonged hyperglycemia** (Increased level of glucose in blood > 180 mg/dl) leads to a complex disorder called **diabetes mellitus** which is associated with loss of glucose through urine and formation of harmful compounds known as ketone bodies.
- Diabetic patients are successfully treated with **insulin therapy**.
- Three hallmark symptoms of diabetes mellitus –
  - **(i)** **Polyuria** (Excessive urination)
  - **(ii)** **Polydipsia** (Excessive thirst)
  - **(iii)** **Polyphagia** (Excessive hunger)
- Other symptoms include – Dehydration, Loss of weight and tiredness.
- Due to active and incomplete decomposition of fats in fatty tissues, ketone bodies are formed which leads to **ketoacidosis**.
- The combined effect of Ketoacidosis, Dehydration and Hyperglycemia may cause **Diabetic Coma** to the patient, patient becomes unconscious and even may die.

Somatostatin :

- Secreted by **δ-cells**
- It **regulates** (inhibits) the **secretion of insulin and glucagon**.

Pancreatic Polypeptide (PP) :

- Secreted by **F-cells / PP-cells**
- Its functions are unknown yet today, perhaps it controls the absorption of food in intestine.

12. Gonads and Other Organs :

(A) Gonads (In Male -Testis) :

- A pair of testis is **present in the scrotal sac (outside abdomen)** of male individuals.
- Testis performs dual functions as a **primary sex organ** as well as **an endocrine gland**.
- Testis is composed of **seminiferous tubules** and **stromal** or **interstitial tissue**.
- The **Leydig cells** or **interstitial cells**, which are present in the intertubular spaces produce a group of hormones called androgens mainly **testosterone**.
- Androgens **regulate the development, maturation and functions of the male accessory sex organs** like epididymis, vas deferens, seminal vesicles, prostate gland, urethra etc.
- These hormones **stimulate muscular growth, growth of facial and axillary hair, aggressiveness, low pitch of voice** etc.
- Androgens play a **major stimulatory role in the process of spermatogenesis** (formation of spermatozoa).
- Androgens **act on the central neural system** and **influence the male sexual behaviour (libido)**.
- These hormones produce **anabolic (synthetic) effects** on protein and carbohydrate metabolism.

(B) Gonads (In Female - Ovary) :

- Females have a pair of ovaries **located in the abdomen**.
- Ovary is the **primary female sex organ** which produces one ovum during each menstrual cycle.
- In addition, ovary also produces two groups of **steroid hormones** called **estrogen** and **progesterone**.
- Ovary is composed of **ovarian follicles** and **stromal tissues**.
- The estrogen is synthesised and secreted mainly by the growing ovarian follicles. After ovulation, the ruptured follicle is converted to a structure called **corpus luteum**, which secretes mainly progesterone.

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- Estrogens produce wide ranging actions such as stimulation of growth and activities of female secondary sex organs, development of growing ovarian follicles, appearance of female secondary sex characters (e.g., high pitch of voice, etc.), mammary gland development.
- Estrogens also regulate female sexual behavior.
- **Progesterone supports pregnancy.**
- Progesterone also acts on the mammary glands and stimulates the formation of alveoli (sac-like structures which store milk) and milk secretion.

(C) Heart :

- The **atrial wall of our heart** secretes a very important **peptide hormone** called **Atrial Natriuretic Factor (ANF)**, which **decreases blood pressure**.
- **When blood pressure is increased**, ANF is secreted which causes dilation of the blood vessels. This reduces the blood pressure.

(D) Kidney :

- The **juxtaglomerular cells** of kidney produce a **peptide hormone** called **Erythropoietin** which stimulates **erythropoiesis** (formation of RBC).

(E) Gastro Intestinal Tract Hormone :

- Endocrine cells present in different parts of the gastro-intestinal tract secrete four major peptide hormones –
  (i) Gastrin
  (ii) Secretin
  (iii) Cholecystokinin (CCK)
  (iv) Gastric inhibitory peptide (GIP)
- **Gastrin** acts on the gastric glands and stimulates the secretion of hydrochloric acid and pepsinogen.
- **Secretin** acts on the exocrine pancreas and stimulates secretion of water and bicarbonate ions.
- **Cholecystokinin (CCK)** acts on both pancreas and gall bladder and stimulates the secretion of pancreatic enzymes and bile juice, respectively.
- **Gastric inhibitory peptide (GIP)** inhibits gastric secretion and motility.
- Several **other non-endocrine tissues** secrete hormones called **growth factors**. These factors are essential for the **normal growth of tissues** and their **repairing/regeneration.**

BEGINNER'S BOX-4 THYMUS, PINEAL, PANCREAS AND OTHER GLANDS

1. Role of thymus in homosapiens is chiefly concerned with :-
(1) Reproduction (2) Immunology (3) Calcium balance (4) Blood coagulation

2. Origin of Thymus Gland is
(1) Ectoderm (2) Endoderm (3) Mesoderm (4) None of above

3. Pineal body originates from :
(1) Dorsal part of diencephalon (2) Ventral part of diencephalon
(3) Ventral part of cerebellum (4) Dorsal part of cerebellum

4. Melatonin is a hormone produced by :-
(1) Adrenal gland (2) Pituitary gland (3) Pineal gland (4) Thymus gland

5. Which hormone influences metabolism, pigmentation, menstrual cycle and our defense capability?
(1) Melatonin (2) Thymosin (3) Thyroxine (4) Epinephrine

6. Which gland is both exocrine as well as endocrine?
(1) Pituitary (2) Mammary gland (3) Thyroid (4) Pancreas

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7. Glucagon is secreted by: -
(1) Leydig cells (2) Islets of Langerhans
(3) Corpus luteum (4) Glisson's capsule

8. Insulin by chemical nature is :-
(1) Carbohydrate (2) Protein (3) Steroid (4) Lipid

9. Following are the principle action of insulin except :-
(1) Increase transport of Glucose in to the cells (2) Stimulate glycogenesis
(3) Promote Glycogenolysis (4) Increase lipogenesis

10. Which hormone has anti insulin effect: -
(1) Cortisol (2) Oxytocin (3) Aldosterone (4) Glucagon

11. Which of the following disease is not caused by hyper/hyposecretion of hormone ?
(1) IDDM (2) NIDDM (3) Acromegaly (4) Myxoedema

12. Diabetes insipidus is due to :-
(1) Hypersecretion of insulin (2) Hyposecretion of vasopressin
(3) Hypersecretion of vasopressin (4) Hyposecretion of insulin

13. Estrogen is secreted by :-
(1) Liver (2) Spleen (3) Ovaries (4) Pituitary

14. Androgens are secreted by :-
(1) Pituitary (2) Testes (3) Ovaries (4) Thyroid

15. The "erythropoietin" hormone regulates :-
(1) Blood pressure (2) Water level of blood
(3) Glucose level of blood (4) Rate of formation of red blood cells

16. Which of the following hormone is not secreted by gastro-intestinal tract ?
(1) Gastrin (2) Secretin (3) Cholecystokinin (4) Erythropoietin

BEGINNER'S BOX — ANSWERS KEY

BEGINNER'S BOX-1									
	Que.	1	2	3	4	5	6	7	
	Ans.	4	1	4	3	4	4	1	

BEGINNER'S BOX-2											
	Que.	1	2	3	4	5	6	7	8	9	
	Ans.	4	1	2	4	2	4	1	3	1	

BEGINNER'S BOX-3											
	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	3	2	2	2	2	3	1	3	4	2
	Que.	11	12								
	Ans.	2	1								

BEGINNER'S BOX-4											
	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	2	2	1	3	1	4	2	2	3	4
	Que.	11	12	13	14	15	16				
	Ans.	2	2	3	2	4	4				

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EXTRA POINTS

- **Heterocrine Gland :-** These are those endocrine glands which are involved in hormone secretion as well as some other function e.g. pancreas, gonads, GI mucosa and kidneys.
- Contrary to thyroid dwarf (cretins), the pituitary dwarf have a normal mental development and proportionate body.
- **Simmond's disease :-** This condition is due to atrophy of the anterior lobe of pituitary gland.
- **Growth hormone :-** Stimulates the liver to form **"Somatomedins"** ("Insulin like growth factors"). These somatomedins have potent effects on bone growth.
- In heart CGMP has antagonistic effect to CAMP, CAMP mediate muscle contraction in response to adrenaline, while CGMP slow down muscle contraction is response to acetylcholine.
- CGMP used in second messenger in atrial natriuretic peptide and nitric oxide.
- Pituitary tumor may cause visual problem because it exerts pressure on optic chiasma and thus affect and transmission of sight impulses.
- The **cortisol** hormone of adrenal cortex serves to maintain the body in living condition and recover it from the severe effects of stress reactions. Thus, an increased output of cortisol is "**life saving**" in "**shock conditions**". So it is also known as **life-saving hormone**.
- The hormones of **adrenal medulla** prepare the animal for fear, fight or flight in emergency conditions, (by excess secretion of these hormones) Adrenaline hormone is called **3F = FFF hormone** and adrenal gland is called "**triple F gland**" (FFF gland).
- The amount of cortisol and ACTH in blood is maximum in the morning and minimum in early part of night.
- Secretion of thymin decreases the neuromuscular transmission, so hypersecretion of thymine may cause ***myasthenia gravis***. It provides the antibody against receptor & block the NM junction.
- **Synergestic hormone** – When two or more hormone complement the function of each other and both are needed for full expression of hormone effect.
  Example : Insulin and growth hormone/Thyroxine have synergestic effect for body growth.
  Estrogen, progesterone, prolactin and oxytocin have synergestic effect for physical growth of mammary gland.
- **Antagonistic hormone** – When two hormones oppose the actions of each other.
  Example : Insulin and glucagon
  Calcitonin and Parathyroid hormone
  MSH and melatonin

  Type – I diabetes or **Insulin-dependent diabets mellitus (IDDM)**
  - Caused by deficiency of insulin.
  - Can be treated by insulin-therapy.
  - It is an example of auto immune disorder.

  Type – II diabetes or **non-insulin-dependent-diabetes mellitus (NIDDM)**
  - It is initially caused by decreased sensitivity of receptors of target tissue to the metabolic effect of insulin. This reduced sensitivity to insulin is often called **insulin resistance.**
  - World diabetes day - 14 November
  - "**Insulin shock**" - At the time of physical labour or fasting, if a diabetic patient takes an insulin injection, sugar level in blood reduces quickly up to 40 mg/100ml of blood. It is called insulin shock. The patient may be unconscious or even may die.
- Melatonin suppress hypothalamus, causes suppression of the anterior pituitary gonadotropins leading to suppression of menstruation and gonadal activity. Does that mean hypothalamus is under control by melatonin?
- Secretin is a First discovered hormone.
- Term "Hormone' is coined by E.H. Starling.

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ESSENCE

HORMONES REGULATE

- **Metabolism**
- **Growth**
- **Developement**

- Hormones are non-nutrient chemicals, which act as intercellular messengers and are produced in trace amounts

PITUITARY GLAND

Pars distalis
- Produce 6 trophic hormones
  - GH
  - TSH
  - ACTH
  - FSH
  - LH
  - PRL
- Growth and development of somatic tissue
- Regulate activities of peripheral endocrine glands

Regulated by Hypothalamic hormones

Pars Intermedia
- Secrete one hormone
  - MSH

Pars Nervosa
- Secrete two hormones
  - ADH
    - Promote reabsorption of water & electrolytes
  - Oxytocin
    - Parturition

Hormones synthesized by hypothalamus

- Pineal Gland → Melatonin → Regulates
  - Diurnal rhythm
  - Body temp.
  - Pigmentation
  - Immune response

PARATHYROID GLANDS

Secretes PTH

Increase Blood calcium

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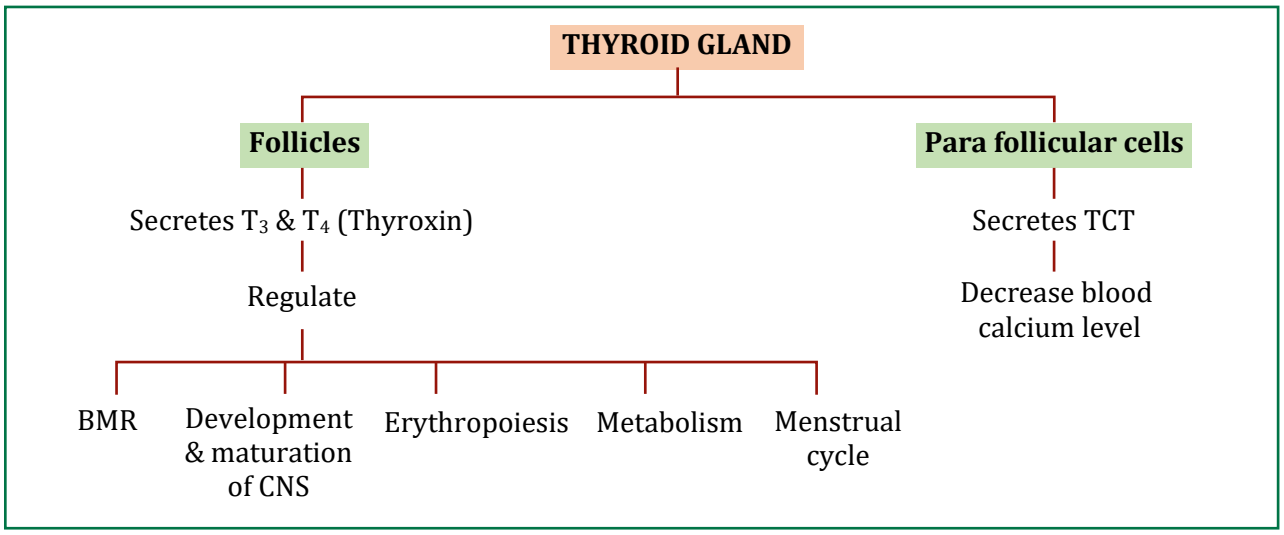

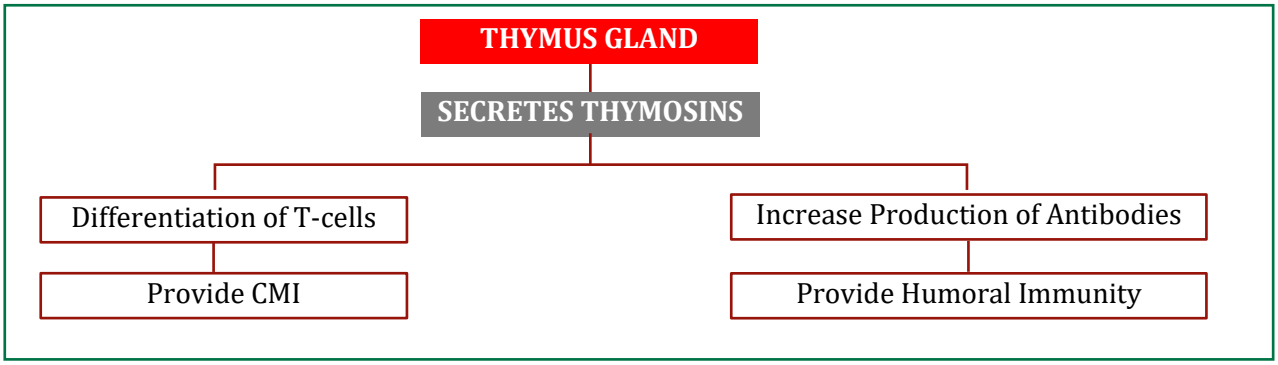

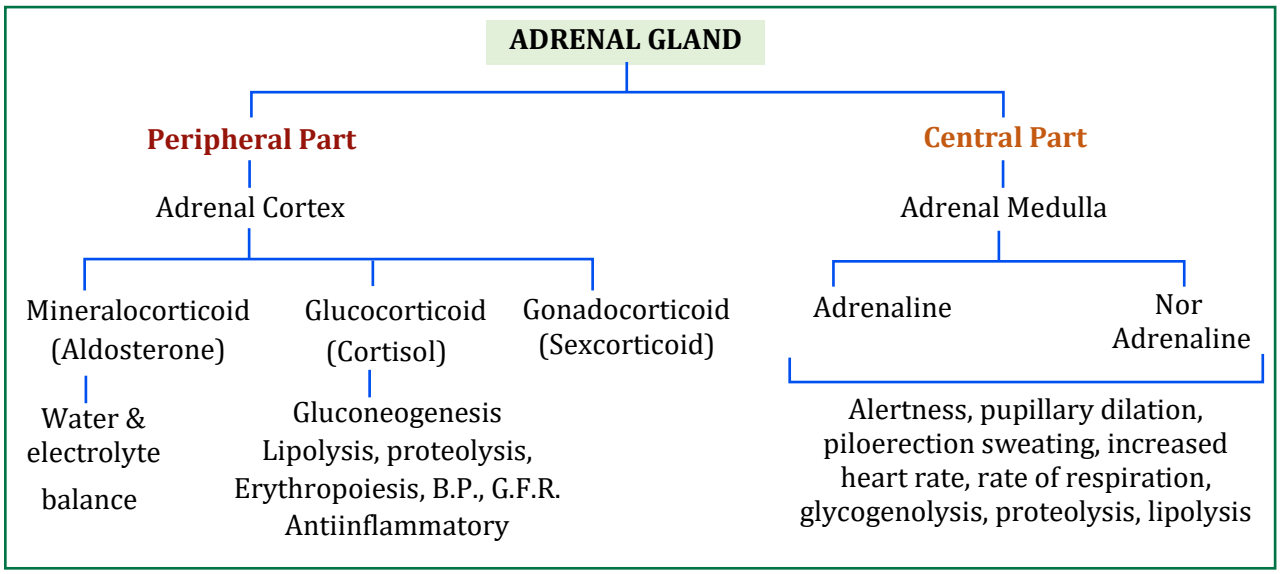

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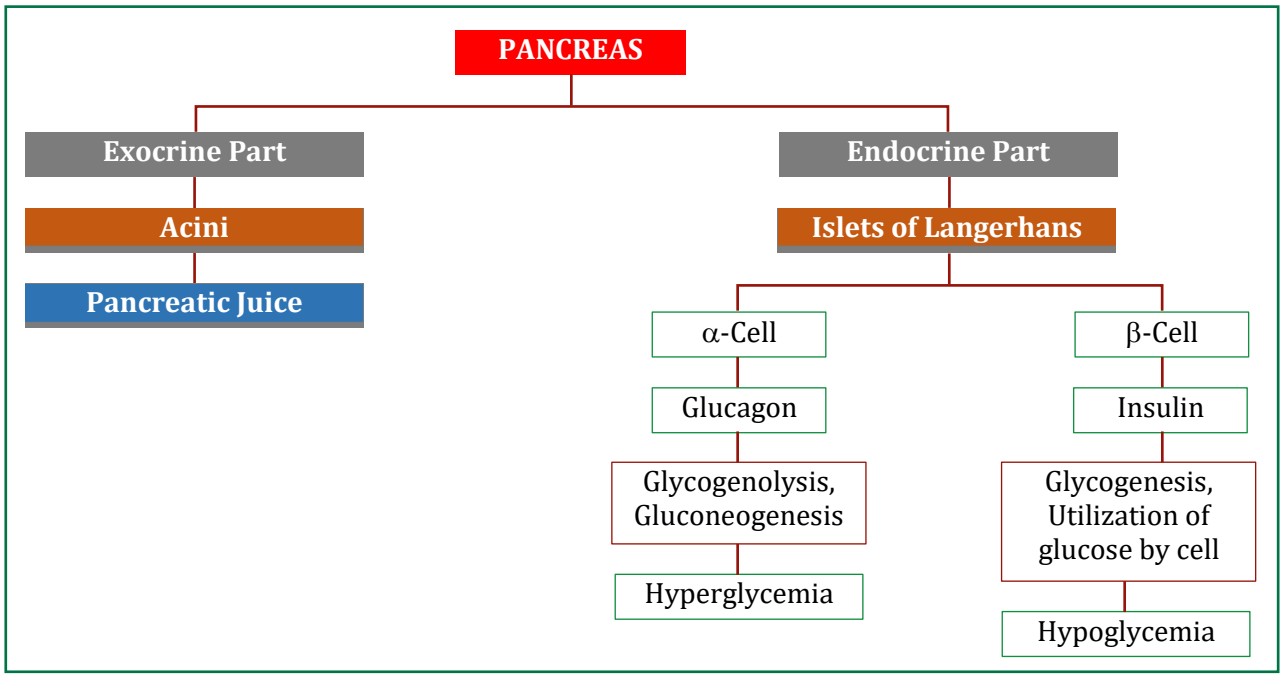

- The testis secretes androgens, which stimulate the development, maturation and functions of the male accessory sex organs, appearance of the male secondary sex characters, spermatogenesis, male sexual behaviour, anabolic pathways and erythropoiesis.
- The ovary secretes estrogen and progesterone.
- Estrogen stimulates growth and development of female accessory sex organs and secondary sex characters.
- Progesterone plays a major role in the maintenance of pregnancy as well as in mammary gland development and lactation.
- The atrial wall of the heart produces atrial natriuretic factor which decreases the blood pressure.
- Kidney produces erythropoietin which stimulates erythropoiesis.
- The gastrointestinal tract secretes gastrin, secretin, cholecystokinin and gastric inhibitory peptide.

Disorders :

- Dwarfism – Deficiency of GH.
- Gigantism – Over secretion of GH in growth age.
- Acromegaly – Over secretion of STH.
- Diabetes insipidus – Deficiency of ADH.
- Cretinism – Deficiency of thyroid hormones in embryo.
- Myxoedema – Deficiency of thyroid hormones in adults.
- Simple goitre – Deficiency of iodine in diet.
- Exophthalmic goitre – Over secretion of thyroid hormones.
- Tetany – Deficiency of PTH
- Osteoporosis – Over secretion of PTH.
- Diabetes mellitus – Deficiency of insulin.